METHOD OF GENERATING CYLINDRICAL MAGNETIC DOMAINS

CROSS REFERENCE TO RELATED APPLICATIONS

The method and apparatus disclosed herein is an improvement over the known prior art manufacturing techniques which were disclosed in my eariler filed applications, Ser. No. 242,474, filed Apr. 10, 1972, and Ser. No. 205,095, filed Dec. 6, 1971, now U.S. Pat. Nos. 3,806,903 and 3,806,899, respectively both of which relate to devices utilizing mobile cylindrical magnetic domains in crystal platelets and both of which are assigned to the Hughes Aircraft Company as is this application.

BACKGROUND OF THE INVENTION

The utilization of mobile or movable cylindrical magnetic domains in certain single crystal ferromagnetic materials which are characterized by a preferred direction of magnetization out of the plane of the sheet of crystal has been disucssed in detail in my above referenced applicaton, Ser. No. 205,095 and in the prior art cited therein and applied thereto. The formation of the cylindrical domains in orthoferrite or garnet crystals was also described in an article in the June, 1971 issue of "Scientific American" entitled "Magnetic Bubbles" by A. H. Bobeck and E. D. Scovil, beinning at page 78. At page 81 therein they point out that as the crystal wafer naturally containing meandering strip domains is immersed in an external magnetic field perpendicular to the wafer and as the filed strength is rasied, the wavy strips whose magnetization is opposed by the filed begin to get narrower and shorter and continue to do so until at a certain field strength all of the island domains or strips not pinned to the edge of the wafer suddenly contract into small cylindrical domains which are called bubbles.

However, this technique of creating bubbles permits one to establish only as many cylindrical domains as there were original island meandering domains naturally occurring in the crystal platelet. If one wishes to create a very large number or foam bubbles, some other technique must be used. The Bobeck article at page 86 shows one bubble generator using a rotating "in plane" field in combination with a bubble nucleating generator spot. Another method for creating a predetermined number of magnetic bubbles in a crystal platelet by means of applying a laser beam to locally heat a predetermined portion of the crystal is described in U.S. Pat. No. 3,786,452, issued to J. E. Geusic on Jan. 15, 1974, and entitled "Single Wall Domain Generator". This technique is particularly suited for generation of an arbitrary number of bubbles in garnets rather than orthoferrites since the Curie temperature for orthoferrites is very much higher than it is for garnets. For example. Geusic at line 57 of column 3 of his patent gives a typical Curie temperature of 127°C for garnet. The corresponding Curie temperature for terbium orthoferrite is 379°C and for yttrium orthoferrite it is 370°C.

Other studies in the past have suggested the possibility of applying a magnetic field parallel to the plane of the crystal rather than perpendicularly to it as discussed above in order to physically break up the meandering domains into smaller domains by forcing them into alignment with one of the hard axes to churn the

domains and thereby increase the number of bubbles. However, this technique is also more readily feasible with garnets than with orthoferrites since the garnet materials have a considerably lower anisotropy field and domain wall energy than do the orthoferrites and thus require a smaller churning field than do the orthoferrites.

These conclusions ae born out by the following studies reported in the scientific literature as noted below.

1. E. Della Torre, "Pressures On Cylindrical Magnetic Domain Walls," TEEE Trans. Mag MAG-**6,** 822–827 (1970).
2. A. J. Perneski, "Propagation of Cylindrical Magnetic Domains in Orthoferrites," IEEE Trans. Mag. MAG-**5,** 554–557 (1969).
3. F. A. De Jonge and W. F. Druyvesteyn, Proceedings of AIP Conference on Magnetism and Magnetic Materials, No. 5, 130–134 (1971).
4. J. A. Cape and G. W. Lehman, "Magnetic Domain Structures in Thin Uniaxial Plates With Perpendicular Easy Axis," J. Appl. Phys. **42,** 5732–5736 (1971).
5. J. M. Nemchik and S. H. Charap, "Measurement of Domain Wall Mobility in GdIG," Met. Trans. **2,** 635–639 (1971).
6. D. J. Craig and D. A. McIntyre, "Critical Fields For Magnetization Reversal in Yttrium Orthoferrite," Phys. Letters **21,** 288–289 (1966).
7. F. B. Hagedorn, J. Appl. Phys. **41,** 1161–1162 (1970).
8. Arjeh Kurtzig and Fred B. Hagedorn "Noncubic Magnetic Anisotropies in Bulk and Thin Film Garnets", IEEE Transactions on Magnetics, MAG. **7** No. 3, pp. 473–476. (Sept. 1971)

A careful review of this literature will indicate that the early orthoferrite investigators only formed singular bubbles with magnetic probes and used complex bubble replicating circuits to do so. They were never able in practice to generate a bubble foam comprising a large number of bubbles with a simple churner in an orthoferrite crystal, although it is possible to generate a bubble foam in a garnet crystal by applying a pulsed magentic field in a direction parallel to the major plane of the crystal in order to churn the domains therein (See Reference 8). In fact, all succesful prior bubble churning studies were applied to garnets which have low anisotropy and wall energies, and form small domains. It is thus quite easy to churn domains in garnets and break them up into cylindrical bubbles.

Cutting of a single elongated domain in orthoferrite was theoretically analyzed by Della Torre (Reference 1 above) and reduced to practice by Perneski (Ref. 2) using special bubble generator circuits. No prior art on the generation of a large number or foam of bubbles in orthoferrites by churning has been found in the literature. The technique of applying a pulsed magnetic filed to the cyrstal can, as noted above, accomplish this churning or domain breakup in garnets with a field of reasonable magnitude applied parallel to the major plane of the crystal or orthogonal to the easy axis of magnetization thereof. Since the domain wall energies in garnets are relatively low, the rotational force on the domains is sufficient to split them with a field of reasonable size. In orthoferrites the anisotropy and domain wall energies are substantially higher and although the same technique can theoretically be used, it requires an inconveniently large magnetic field and has not been achieved in practice.